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## Challenges in identifying (or not) focal animal sound production in baleen whale acoustic tag datasets

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also often measured by the tag. Use of passive acoustic tags with echolocating animals has opened a new window on how toothed whales echolocate to find, approach, and capture prey, especially when the tags also include three-axis accelerometry and magnetometry to measure orientation and movement. The combination of these tags with passive acoustic monitoring provides a powerful method to improve localization, to estimate the three dimensional beam pattern of sound production, and to estimate the absolute abundance of species that vocalize.

8:20

**2aAB2. Acoustic time synchronization among tags on porpoises to observe their social relationships.** Tomonari Akamatsu (Res. Ctr. for Fisheries System Eng., Fisheries Res. Agency & JST CREST, 7620-7, Hasaki, Kamisu, Ibaraki 314-0408, Japan, akamatsu@affrc.go.jp), Mai Sakai (Wildlife Res. Ctr., Univ. of Kyoto & JSPS, Kyoto, Japan), Ding Wang, Kexiong Wang, and Songhai Li (Key Lab. of Aquatic Biodiversity and Conservation of the Chinese Acad. of Sci., Inst. of Hydrobiology of the Chinese Acad. of Sci., Wuhan, China)

Observing and monitoring underwater social interactions of cetaceans is challenging. Because cetaceans spend most of their time underwater, it is important to monitor their underwater behavior individually. The finless porpoise is small and has no available natural identification marks that causes little knowledge of its sociality. Here we used acoustic datalogger to synchronize individual depth profile among individuals within a second. Acoustic and behavior tags were deployed on six free-ranging finless porpoises simultaneously and released in open water. Echolocation sounds were used as the trigger signal to synchronize the clock of all logging systems. Synchronous dives characterized by similar time-depth profile were used as an index of association. Two pairs tended to participate in long periods of synchronized diving more frequently than 13 other possible pairs, indicating that these four porpoises chose their social partners. Initiator and follower could be identified by precisely time synchronized data. The adult males tended to follow the immature female and juvenile male, respectively. However, the role of an initiator often changed within the pair during synchronized diving, and their body movements appeared to be non-agonistic. The time-synchronized bio-logging method was useful for observation of the social relationships of free-ranging aquatic animals.

8:40

**2aAB3. Studying acoustic communication in pilot whale social groups.** Frants H. Jensen (Biology, Woods Hole Oceanographic Inst., 266 Woods Hole Rd., M.S. # 50, Woods Hole, MA 02543, frants.jensen@gmail.com) and Peter L. Tyack (Scottish Oceans Inst., Univ. of St Andrews, St Andrews, United Kingdom)

Many cetaceans are gregarious animals with a complex group structure, and they depend on acoustic signals for mediating social interactions among individuals. However, the marine lifestyle and closed sound production system makes it difficult to study social signaling in groups of wild cetaceans. Acoustic and movement logging tags offer new possibilities for sampling the sounds and behavior of individuals, but themselves provide new challenges in determining the source of acoustic signals. Here, we draw on experiences from studies of short-finned and long-finned pilot whales to discuss how social signaling can be investigated in wild marine mammals. We discuss how specific social contexts, especially separations from the social group, can aid the interpretation of individual tag data to test whether calls of short-finned pilot whales are important in mediating social contact with group members, while emphasizing the pitfalls of using such methods. Specifically, we highlight the advantages of simultaneously instrumenting multiple closely associated pilot whales with acoustic and movement recording tags. This has improved our understanding of acoustic interactions through ready identification of the sender and simultaneously monitoring the reaction of other group members, and we use this dataset to discuss ongoing challenges of studying social dynamics using simultaneous tag deployments.

9:00

**2aAB4. Insights into a complex communication system from tagged bottlenose dolphins.** Laela Sayigh (Biology Dept., Woods Hole Oceanographic Inst., M.S. #50, Woods Hole, MA 02543, lsayigh@whoi.edu), Vincent Janik (Biology Dept., Univ. of St. Andrews, St. Andrews, United Kingdom), Frants Jensen (Biology Dept., Woods Hole Oceanographic Inst., Woods Hole, MA), Katherine McHugh, Randall Wells (Sarasota Dolphin Res. Program, Chicago Zoological Society, c/o Mote Marine Lab., Sarasota, FL), and Peter Tyack (Biology Dept., Univ. of St. Andrews, St. Andrews, United Kingdom)

Since 2011, we have deployed 30 acoustic and movement logging DTAGs on long-term, multi-generational resident bottlenose dolphins in Sarasota Bay, Florida, for a total of approximately 140 h. Twenty-two tags were deployed simultaneously on pairs of associated individuals, allowing for greater resolution of individual vocal activity. Virtually all dolphins in the Sarasota Bay community are identifiable both visually and by means of their individually distinctive signature whistles. Tags were attached during brief capture-release health assessments, and behavioral observations of tagged individuals post-release continued for as long as possible. Tag data reveal unique insights into foraging behavior, including distinctive acoustic and movement patterns associated with particular foraging modes (e.g., "pinwheel feeding"). In addition to echolocation clicks and buzzes, several distinctive pulsed sounds were recorded on the tags. Whistle copying was observed 18 times in a preliminary analysis of approximately two hours of data, and at least one instance involved more than two dolphins producing the same whistle. Finally, we obtained evidence for at least one shared, stereotyped non-signature whistle. Combining extensive longitudinal information on individual dolphins with fine scale behavioral and acoustic data provides tremendous opportunities for describing and quantifying the complexity of the bottlenose dolphin communication system.

9:20

**2aAB5. Challenges in identifying (or not) focal animal sound production in baleen whale acoustic tag datasets.** Alison K. Stimpert (Dept. of Oceanogr., Naval Postgrad. School, Monterey, CA 93943, alison.stimpert@gmail.com), Doug P. Nowacek (Nicholas School, Duke Univ., Beaufort, NC), Ari S. Friedlaender (Southall Environ. Associates, Inc., Aptos, CA), Jan Straley (Biology, Univ. of Alaska Southeast, Sitka, AK), David W. Johnston (Nicholas School, Duke Univ., Beaufort, NC), Jeremy A. Goldbogen (Cascadia Res. Collective, Olympia, WA), and Ching-Sang Chiu (Dept. of Oceanogr., Naval Postgrad. School, Monterey, CA)

Ascribing sounds on animal-borne tag recordings to individual sound producers is integral to understanding social behavior of animal groups. Previously, sounds recorded on tags have been assigned to the tagged individual (focal animal) based on proximity of other conspecifics, angle of arrival, low frequency artifacts in the sound, or a combination of signal-to-noise ratio (SNR) and received level (RL). However, most acoustic-based methods do not translate well to baleen whales producing low frequency sounds, as the tag often resides in the near field of the sound source. In addition, for social species that spend time in groups with conspecifics in close proximity,

sounds produced by nearby animals may have comparably high SNR and RL. Here we discuss the challenges of determining if a tagged whale is calling in baleen whale datasets, using acoustic records from two humpback whales, one fin whale, and one blue whale as examples. The datasets include intense song or feeding calls and are from several locations. We compare SNR, RL, harmonic content, and behavioral sensor data in these cases, and discuss the implications of confirming sound production by a tagged individual for measuring communication, behavior, and responses to external stimuli in baleen whales.

9:40

**2aAB6. Tags, drifters, and Towfish: Using multiple recording platforms to characterize odontocete acoustic space.** T. A. Mooney, Maxwell B. Kaplan (Biology Dept., Woods Hole Oceanographic Inst., 266 Woods Hole Rd., Woods Hole, MA 02543, amoney@whoi.edu), Robin W. Baird (Cascadia Res. Collective, Olympia, WA), and Jim Partan (Appl. Ocean Phys. and Eng. Dept., Woods Hole Oceanographic Inst., Woods Hole, MA)

Bioacoustic tags can reveal novel information about the behavior and ecology of animals on which they are deployed. Yet tags are often placed off the animals' acoustic axis, limiting some potential analyses. In order to broaden abilities to examine bioacoustic signals and behavior of several Hawaiian odontocetes we adapted recording methods to enhance data collection opportunities and free-field records. While bioacoustic DTAGs were deployed, we also used DMONs (digital acoustic recorders) in both a GPS-outfitted drifter buoy (Drifting Acoustic Wideband Gizmo = DAWG) and a Towfish around pantropical spotted dolphins (*Sa*), melon-headed whales (*Pe*), and short-finned pilot whales (*Gm*). Daytime tag recordings show *Pe* and *Sa* were limited to relatively shallow dives (< 50 m) but were relatively soniferous, whereas *Gm* made occasional deeper dives (to 700 m) and fewer individual calls. Group measures for *Pe* and *Sa* from the DAWG and Towfish revealed relatively high incidences of overlapping calls. Preliminary investigations of *Pe* whistles suggest some limited variation between *Pe* populations and considerable variability in individual call types. Such characterizations of call rates and variability support efforts to detect and classify odontocete calls. The different methods provided complementary means to collect substantial bioacoustic data on pelagic odontocetes for which few data exist.

10:00–10:15 Break

10:15

**2aAB7. Classification of behavioral state using hidden Markov model analysis of animal-attached tag data: Applications and future prospects.** Patrick J. Miller and Saana Isojunno (School of Biology, Univ. of St Andrews, Bute Bldg., St Andrews, Fife KY16 9QQ, United Kingdom, pm29@st-andrews.ac.uk)

Data from high-resolution animal-attached tags enable quantification of behavioral responses to anthropogenic noise. However, the duration of such detailed tag records on marine divers are typically too short to allow evaluation of the biological significance of such effects. To explore whether and how sperm whale behavior changed during exposure to sonar, we developed a discrete-time hidden activity state model that describes how observed parameters derived from measured Dtag data (depth, pitch, and clicking behavior) arise from five behavioral modes (surfacing, descent, bottom phase, ascent, resting, and silent active). Although the model assumed simple Markovian state-transitions, the state classification matched well with expert judgment of dive state. During experimental exposures to 1–2 kHz sonar, all four sperm whales tested reduced foraging time, increased silent active behavior, and buzz rates during foraging states decreased. None of those effects were found during 6–7 kHz experimental exposures of the same four whales, nor for three other whales exposed to distant sonar. Hidden classification of behavioral state using quantitative analysis of data collected by the animal attached tag is a procedure that has the potential to be processed autonomously on-board tags. This would enable collection and satellite telemetry of longer-term behavioral data sets with biologically significant interpretations.

10:35

**2aAB8. Statistical analysis of data from acoustic tags: Methods for combining data streams and modeling animal behavior.** Stacy L. DeRuiter, Catriona Harris, Dina Sadykova, and Len Thomas (School of Mathematics and Statistics, Ctr. for Res. into Ecological and Environ. Modelling, Univ. of St. Andrews, CREEM, St. Andrews KY16 9LZ, United Kingdom, sldr@st-andrews.ac.uk)

Statistical analysis of data from multi-sensor acoustic tags presents several characteristic challenges. Datasets generally include time-series of many measurements on a small number of individuals; different data streams often have distinct temporal resolutions and precisions. The MOCHA project (Multi-study Ocean acoustics Human effects Analysis) is a three-year effort focused on developing innovative statistical methods for such data. Here, we present several approaches for appropriate, effective statistical analysis of such datasets, with an emphasis on quantitative assessment of changes in marine mammal behavior in response to acoustic disturbance. Issues to be addressed will include: combining data streams from multi-sensor tags (and also concurrent visual observation data) for statistical analysis; statistical methods to characterize or summarize normal behavior and detect departures from normal; methods for analysis of call-production-rate data from acoustic tags; and methods for combining analysis of data from multiple tags, individuals, and species. Specific statistical methods to be presented will include Mahalanobis distance as a summary of multivariate data, state-switching models, random effects, and other extensions of generalized linear models appropriate to tag data.

10:55

**2aAB9. Using acoustic tags to investigate sound exposure and effects on behavior in endangered killer whales (*Orcinus orca*).** Marla M. Holt, M. Bradley Hanson, Candice K. Emmons (Conservation Biology Div., NOAA NMFS NWFS, 2725 Montlake Blvd. East, Seattle, WA 98112, Marla.Holt@noaa.gov), Juliana Houghton (School of Aquatic and Fishery Sci., Univ. of Washington, Seattle, WA), Deborah Giles (Dept. of Wildlife, Fish and Conservation Biology, Univ. of California, Davis, Seattle, CA), Robin W. Baird, and Jeff Hogan (Cascadia Res. Collective, Olympia, WA)

In this investigation, acoustic tags (DTAGs) allow us to better understand noise exposure and potential behavioral effects in endangered Southern Resident killer whales (SRKWs). Designated critical habitat of SRKWs includes summer foraging areas where vessel traffic from commercial shipping, whale-watching, and other boating activities is common. Risk factors of population recovery include